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Shipley

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(54) **POWER CONTROLLER SYSTEM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 818 days.

(21) Appl. No.: **13/278,206**

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(30) **Foreign Application Priority Data**

Oct. 22, 2010 (GB) 1017887.9

(51) **Int. Cl.**

G05F 3/02	(2006.01)
H02H 1/04	(2006.01)
H02H 3/06	(2006.01)
H02H 3/22	(2006.01)
H02H 3/093	(2006.01)
H02H 3/087	(2006.01)

(52) **U.S. Cl.**

CPC ***H02H 3/06*** (2013.01); ***H02H 3/093*** (2013.01); ***H02H 3/22*** (2013.01); *H02H 3/087* (2013.01)

(58) **Field of Classification Search**

CPC G05F 3/02; H02H 1/04; H02H 3/22; H02H 3/06

USPC 307/125, 130, 131; 361/118

See application file for complete search history.

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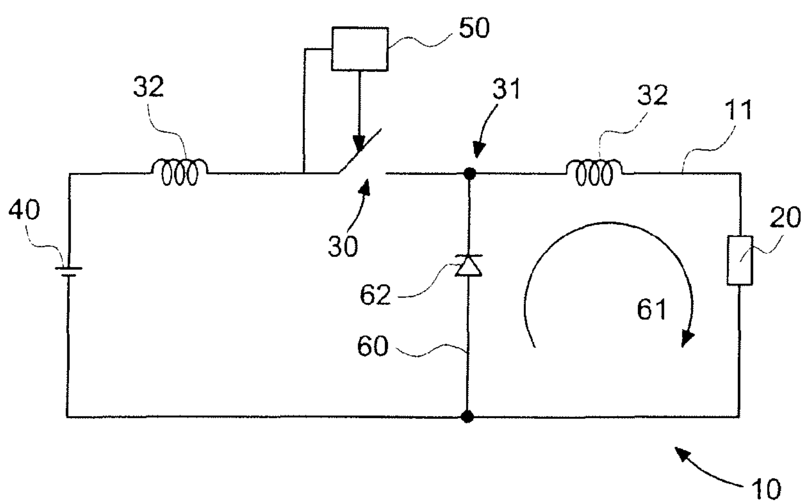
(57) **ABSTRACT**

A power controller system configured to electrically supply a load via a circuit is provided. The system comprises, a switching device provided in an electrical pathway for supplying current to the load, a controller configured to open the switching device when a current through or voltage across the switching device exceeds a predetermined level; and an electrical pathway provided parallel to the load to enable load current to continue to flow through the parallel electrical pathway and the load when the switching device is open to dissipate inductive energy stored in the circuit connecting the parallel electrical pathway to the load.

12 Claims, 2 Drawing Sheets



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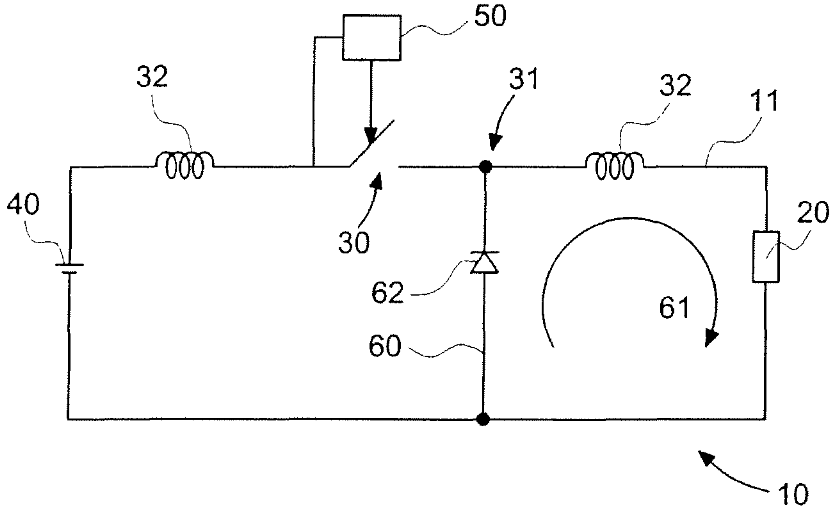
50
32
31
32
11
40
30
20
62
61
60
10

FIG. 1

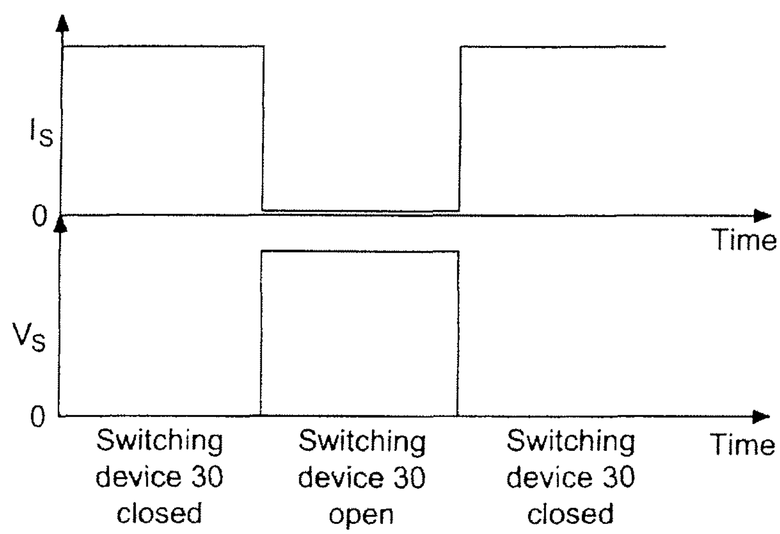
Is
0
Time
Vs
0
Switching device 30 closed
Switching device 30 open
Switching device 30 closed
Time

FIG. 2

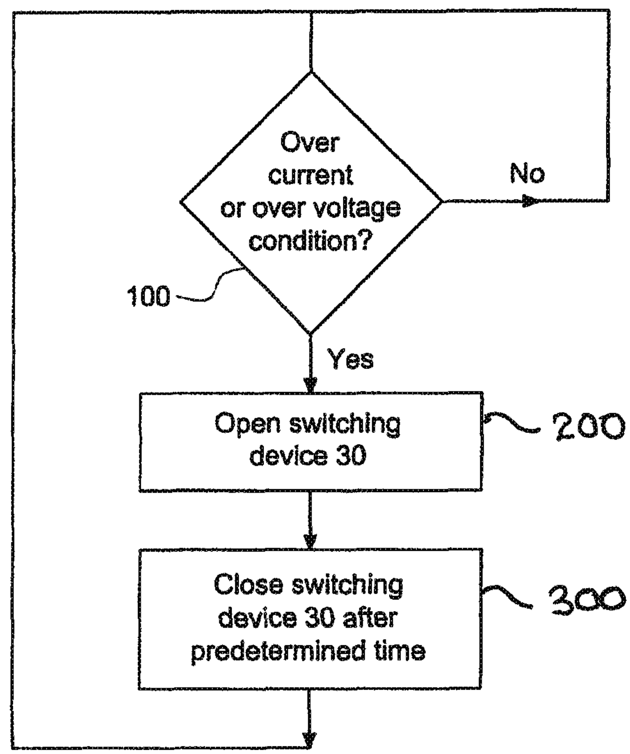
Over current or over voltage condition?
No
100
Yes
Open switching device 30
200
Close switching device 30 after predetermined time
300

FIG. 3

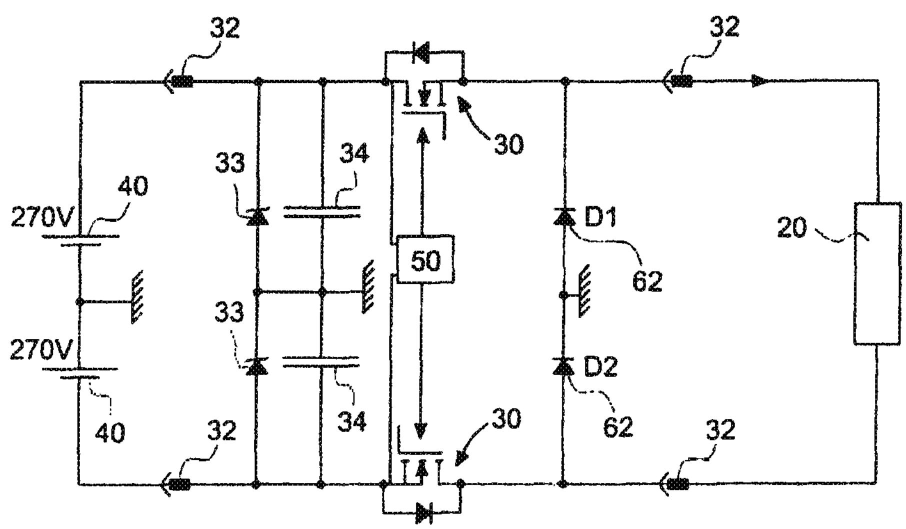
32
32
30
33
34
40
270V
D1
20
62
50
33
270V
34
D2
40
32
34
30
62
32

FIG. 4

POWER CONTROLLER SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The field of the invention relates to a power controller system, in particular to a power controller system which is protected from lightning strikes or fault conditions for example.

2. Description of Related Art

Traditionally a power controller system includes a switching device such as an electro-mechanical switch to interrupt the supply of electrical power to a load in the event of a lightning strike or fault condition. However, in order to try to provide faster reaction times and reduce the size and cost of switching devices, faster operating devices are being used such as micro-electromechanical switches (MEMS) and transistors, such as MOSFETs. Although these devices are faster in operation, their size is proportional to the fault transient that they can accommodate. As they generally have a relatively low thermal mass, they can only accommodate a limited fault transient.

In aviation applications, such as in an aircraft, it is important that a fault condition or lightning strike does not interrupt the current to a given load which may be crucial to the aircraft such as, for example, cockpit controls and instruments, landing gear, engine control, environmental systems etc. Furthermore, electrical power distribution in the aviation industry is moving to higher and higher voltage architectures such that the fault current and environmental considerations such as lightning strikes are becoming more and more severe. Traditionally the power distribution system is over engineered, for example with the transistor switch being much larger to he able to absorb such events as lightning strikes and faults without interrupting the load during such transients. However, over engineering the power distribution system and switches increases cost, size and weight, reducing an aircraft's range and increasing its fuel consumption.

BRIEF SUMMARY OF THE INVENTION

One embodiment of the present invention provides a power controller system configured to electrically supply a load via a circuit. The system comprises a switching device provided in an electrical pathway for supplying current to the load, a controller configured to open the switching device when a current through or voltage across the switching device exceeds a predetermined level; and an electrical pathway provided parallel to the load to enable load current to continue to flow through the parallel electrical pathway and the load when the switching device is open to dissipate inductive energy stored in the circuit connecting the parallel electrical pathway to the load.

During a fault transient scenario, such as a lightning strike when the current through the switching device exceeds a predetermined level, for example ten times the intended current, the switching device will be commanded off by the controller. During this time, the load current will continue to flow through the electrical pathway parallel to the load, dissipating the inductive energy stored in the circuit cables connecting the distribution system and the load. Consequently, the load current will not be interrupted which is very important in aviation for example, for systems relied upon by an aircraft during flight.

An alternate embodiment of the present invention provides a method of operating a power controller system configured to electrically supply a load via a circuit. The method comprises opening a switching device in an electrical pathway for supplying a current to the load when a current through or voltage across the switching device exceeds a predetermined level such that the load current continues to flow through the load, and an electrical pathway in parallel with the load to dissipate inductive energy stored in the circuit including and connecting the parallel electrical pathway to the load.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. **1** shows a power controller system with a load illustrating an example of an embodiment of the present invention;

FIG. **2** is a graph illustrating the voltage across a switching device and. current through an electrical pathway parallel to the load during opening and closing of the switching device in accordance with embodiments of the present invention;

FIG. **3** shows a flow diagram illustrating a method of an embodiment of the present invention; and

FIG. **4** show a more detailed example of a power controller system illustrating an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** shows a power controller system **10** arranged to electrically supply a load **20**. The power controller system includes a circuit **11** comprising a switching device **30** provided in an electrical pathway **31** for supplying current to the load. **20**, The electrical pathway **31** includes an electrical supply **40** connected to the switching device **30** which, in turn, is connected to the load **20**. In practice, the electrical pathway **31** may generally comprise electrical cables or the like which may be several metres or several tens of metres long, depending upon the aircraft, and which inherently provide a certain amount of inductance indicated in FIG. **1** by symbols numbered **32**.

A controller **50** is arranged to open the switching device **30** when a current through or voltage across the switching device **30** exceeds a predetermined level, The controller **50** is preferably connected to the electrical pathway **31** to detect the current passing therethrough or voltage across the switching device **30**. The controller **50** may include a suitable control means such as a micro processor to open the switching device **30** when the detected current or voltage exceeds the predetermined level. The switching device **30** may be any suitable device such as a transistor, for example a MOSFET, a MEMS or an electro-mechanical switch for example.

An electrical pathway **60** is provided parallel to the load **20**. When the controller **50** opens the switching device **30**, disconnecting the supply **40** from the load **20**, current is able to continue to flow through the parallel electrical pathway **60** and the load **20** as indicated by the arrow **61** to dissipate inductive energy **32** stored in the circuit connecting the parallel electrical pathway **60** to the load **20**, The circuit will typically be formed from cables or the like. The parallel electrical pathway **60** may include a diode **62** to ensure that current continues to flow through the load **20** in the same direction as when the switch **30** was closed.

The controller **50** is preferably arranged to close the switching device **30** again after a predetermined, period of time. This predetermined period of time will be dependent upon the amount of inductance in the circuit connecting the parallel electrical pathway **60** to the load **20** and the likely duration of a transient event, such as a lightning strike or the time for a fault to be automatically corrected. This predetermined period of time may, for example, be a few microseconds, tens of microseconds or longer depending upon the amount of inductance in the system, which may be parasitic or may include the effect of added components, The inductance in the circuit connecting the parallel electrical pathway **60** to the load **20** may be appropriate to provide sufficient time for a current to be maintained as indicated by arrow **61** such that the transient event will have substantially subsided by the time that the switch **30** is closed again. However, if necessary additional inductances may be provided between the load **20** and the parallel pathway **60**. After this predetermined period of time has elapsed, the controller **50** closes the switching device **30** so that electrical power may again be provided by the supply **40**. This will refresh the inductance in the circuitry connecting the load **20** to the parallel electrical pathway **60**. However, if the current through or voltage across the switching device **30** still exceeds the predetermined level, the controller **50** will open the switching device again such that the inductive energy **32** provided in the circuitry or cabling connecting the parallel electrical paths **60** and the load **20** will again be dissipated,

The controller may continue to turn the switching device **30** on and, off until the transient event has passed or the fault has been corrected.

The example illustrated in FIG. **1** enables current to be continued to be supplied to a load **20** even in the event of a transient event, such as a lightning strike or a fault. This is of particular importance where it is desired to continue to supply a load even in the event of such a transient lightning strike or fault, for example in essential components in an aircraft such as cockpit or engine controls. This is achieved without having to over-engineer switching components as in the prior art, reducing costs and weight.

FIG. **2** illustrates the current I_S through the switching device **30** and the voltage V_S across the switching device **30** during the switching on and off of the switching device **30**. As can be seen from FIG. **2**, with the switching device **30** closed there is a current I_S through it and no voltage V_S across it. However, when a fault is detected with a current or voltage exceeding a predetermined level, the switching device **30** is opened such that there is no longer any current I_S through the switching device **30** and a voltage V_S is then provided across it. A current then flows through the parallel electrical pathway **60**. After a predetermined period of time, during which the transient will have subsided considerably, the controller **50** closes the switching device **30** again resuming the current I_S through the switching device **30** and ceasing the flow of current through the parallel electrical pathway **60**.

If it is found that the voltage across or current through the switching device **30** still exceeds the predetermined level the switching **30** is opened for a second time. If necessary, the switching device **30** can be repeatedly opened and closed until the fault condition has subsided. Each closing of the switching device **30** will refresh the inductance **32** in the circuit, such as cables, connecting the load **20** with the parallel electrical pathway **60**.

FIG. **3** is a flow diagram illustrating a method of operating a power controller system of an embodiment of the present invention. At time step **100** the controller **50** detects whether there is an over current or voltage condition. If there is an over current or voltage deleted, at step **200** the switching device **30** is opened ceasing the flow of current from the generator or supply **40**. Whilst the switching device **30** is open, current continues to flow through the load **20** due to the inductance of the circuit **31** and the parallel electrical pathway **60**.

At step **300** the controller closes the switching device **30** after a predetermined period of time after which the transient is likely to have subsided considerably. After closing the switching device **30**, the controller **50** returns to step **100** at which it determines if there is an over current or over voltage condition at the switching device **30**. If the transient has subsided sufficiently for the current through or voltage across the switching device **30** to be less than the predetermined levels, the switching device **30** remains closed. However, if the current through or voltage the switching device **30** is still above the predetermined level the sequence of steps **200**, **300** illustrated, in FIG. **3** is repeated.

FIG. **4** shows a more detailed example of a power controller system illustrating an embodiment of the present invention. As can be seen from FIG. **4**, many of the components are equivalent to those shown in FIG. **1** and are provided with the same reference numerals. The power controller system illustrated in FIG. **4** shows a possible architecture for a plus/minus 270 V DC distribution system. The switching devices **30** in this example are MOSFETs, but other switching devices such as MEMs or IGBTS may be used. During a fault transient scenario such as a lightning strike, when the current through the MOSFETs **30** exceeds a predetermined level (for example, 10 times the intended protection current) MOSFETs **30** will be commanded off by the controller **50**. During this time the load current will continue to flow through the commutation diodes **62** dissipating the inductive energy stored in the cables and any inductive elements **32** connecting the system to the load **20**. Diodes **33** and capacitors **34** are configured to form clamping circuits for the power controller system illustrated in FIG. **4**.

The switching devices **30** will be commanded back on by the controller **50** a short duration later, by which time the transient will have subsided considerably. The net effect is that the load current was not interrupted during the transient and the full transient energy was not experienced by the MOSFETs,

This technique provides the capability of a digital current limit for electrical power distribution purposes, removing the need for over engineering the switching components thus saving cost and weight.

Many variations may he made to the examples described above without departing from the scope of the present invention. For example, any number of loads **20** may be provided in the circuit or any number of circuits may be provided. Although described with reference to examples in the aviation industry, embodiments the present invention may be used in a power controller system in any application, for example a ship, a vehicle, a factory, a power supply grid or the home.

What is claimed is:

1. A power controller system configured to electrically supply a load via a circuit, the system comprising:
- a switching device provided in a first electrical pathway for supplying current to the load;
- a controller configured to open the switching device when a current through or voltage across the switching device exceeds a predetermined level; and
- a second electrical pathway provided parallel to the load and electrically coupled to the first electrical pathway when a state of the switching device is closed, a first inductive element in the second electrical pathway coupled in series with the load and configured to enable load current to continue to flow through the second electrical pathway and the load when the switching device is open to dissipate inductive energy stored in a second inductive element connecting the second electrical pathway to the load.

2. The system according to claim **1**, wherein the second electrical pathway is configured such that the inductive energy stored in the circuit continues to flow in the same direction as when the switching device was closed.

3. The system according to claim **2**, wherein the second electrical pathway includes a diode to ensure that the inductive energy stored in the circuit continues to flow in the same direction as when the switching device was closed.

4. The system according to claim **1**, wherein the controller is configured to close the switching device after a predetermined period of time.

5. The system according to claim **4**, wherein the controller is configured to open the switching device again if the current through or voltage across the switching device still exceeds the predetermined level.

6. The system according to claim **1**, further comprising a second inductive element to increase the inductance between the parallel electrical pathway and the load.

7. An aircraft including a power controller system configured to electrically supply a load via a circuit, the system comprising:

a switching device provided in a first electrical pathway for supplying current to the load;

a controller configured to open the switching device when a current through or voltage across the switching device exceeds a predetermined level; and

a second electrical pathway provided parallel to the load for providing current to the load, the second electrical pathway coupled to the first electrical pathway, and a first inductive element coupled in series to the second electrical pathway when the switching device is closed, the second electrical pathway configured to enable load current to continue to flow through the second electrical pathway and the load when the switching device is open to dissipate inductive energy stored in the first inductive element connecting the second electrical pathway to the load.

8. A method of operating a power controller system configured to electrically supply a load via a circuit, the method comprising;

arranging, in parallel with a load, a first electrical pathway for supplying current to the load, and coupling the first electrical pathway with a second electrical pathway comprising a first inductive element coupled in series with the load; and

opening a switching device in the first electrical pathway for supplying the current to the load when a current through or voltage across the switching device exceeds a predetermined level;

wherein the load current continues to flow through the load and the second electrical pathway with the load to dissipate inductive energy stored in the first inductive element connecting the second electrical pathway to the load.

9. The method according to claim **8**, further comprising closing the switching device a predetermined period of time after it was opened.

10. The method according to claim **9**, further comprising opening the switching device again if the current through or voltage across the switching device still exceeds the predetermined level.

11. The method according to claim **10**, further comprising repeatedly opening and closing the switching device until the current through or voltage across the switching device no longer exceeds the predetermined level.

12. A method of operating a power controller system of an aircraft the method comprising:

arranging, in parallel with a load, a first electrical pathway for supplying current to the load, and coupling the first electrical pathway with a second electrical pathway comprising a first inductive element coupled in series with the load; and

opening a switching device in the first electrical pathway for supplying the current to the load when a current through or voltage across the switching device exceeds a predetermined level;

wherein the load current continues to flow through the load and the second electrical pathway to dissipate inductive energy stored in the first inductive element connecting the second electrical pathway to the load.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,118,177 B2
APPLICATION NO. : 13/278206
DATED : August 25, 2015
INVENTOR(S) : Shipley

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 1, Line 33, delete "he" and insert -- be --, therefor.

In Column 2, Line 5, delete "load," and insert -- load --, therefor.

In Column 2, Line 18, delete "and." and insert -- and --, therefor.

In Column 2, Line 32, delete "load. 20," and insert -- load 20. --, therefor.

In Column 2, Line 42, delete "level," and insert -- level. --, therefor.

In Column 2, Line 57, delete "load 20," and insert -- load 20. --, therefor.

In Column 2, Line 63, delete "predetermined," and insert -- predetermined. --, therefor.

Signed and Sealed this
Eighth Day of March, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office